Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Review

Prevention and control of COVID-19 in public transportation: Experience from China

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ABSTRACT

Due to continuous spread of coronavirus disease 2019 (COVID-19) worldwide, long-term effective prevention and control measures should be adopted for public transport facilities, as they are increasing in popularity and serve as the principal modes for travel of many people. The human infection risk could be extremely high due to length of exposure time window, transmission routes and structural characteristics during travel or work. This can result in the rapid spread of the infection. Based on the transmission characteristics of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and the nature of public transport sites, we identified comprehensive countermeasures toward the prevention and control of COVID-19, including the strengthening of personnel management, personal protection, environmental cleaning and disinfection, and health education. Multi-pronged strategies can enhance safety of public transportation. The prevention and control of the disease during the use of public transportation will be particularly important when all countries in the world resume production. The aim of this study is to introduce experience of the prevention and control measures for public transportation in China to promote the global response to COVID-19.

1. Introduction

The pandemic of coronavirus disease 2019 (COVID-19) has recently been spreading rapidly worldwide, posing a formidable threat to global public health. According to the World Health Organization (WHO), COVID-19 has affected over 200 countries and regions with more than 19.46 million confirmed cases by August 9th, 2020 (World Health Organization, 2020). Due to its continuous spread worldwide, long-term effective prevention and control measures should be adopted for different settings and vulnerable groups during this pandemic. Public transportation is a primary, and sometimes the only mode of travel for many people.

Public transport vehicles are confined spaces that are conducive for human-to-human transmission of infectious diseases. Consequently, several countries have reported many clusters of cases in public transport vehicles with infections caused by respiratory viruses, including Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). For general influenza, a study in Nottingham reported that the chance of developing influenza increased by six-fold for people traveling by public transport within five days of symptom onset. People within five days of symptom onset generally do not develop flu symptoms but remain contagious, increasing the infection risk of influenza(Troko et al., 2011). Other studies have reported that COVID-19 occurred during bus travel (Technology Daily, 2020; Chen et al., 2020). For SARS-CoV-2, recent findings showed a strong and significant association between COVID-19 and travel by train (Zhao et al., 2020a) and airplane (Associated Press,

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2020; Shanghai Hotline, 2020). For example, on April 8th, 25 people boarding on a flight from Moscow to Beijing were diagnosed with COVID-19 (Global Time, 2020). Passengers in airplane cabin had high risks of airborne infectious diseases because the transmission of microorganisms in cabin was influenced by exhaust ventilation, turbulent diffusion, and advective velocity (Gupta et al., 2012). The confined aircraft cabin exposes travellers to hypobaric hypoxia, dry humidity, and close proximity to the others. Most commercial aircrafts in service recirculate 50% of the air delivered to the passenger cabin. The structural characteristics of airplanes and the mode of mixed ventilation increased the chances of viral spread in the cabin. In a simulation experiment, researchers found that aerosols produced by human coughing were easily spread in the entire cabin in 20 s (Acikgoz et al., 2011). A study exploring the transmissions of COVID-19 on Diamond Princess estimated that the mean reproduction number (R0) in the confined setting reached values up to 11, which was much higher than the mean that estimated from community-level transmission dynamics in China (Mizumoto et al., 2020; Moriarty et al., 2020; Zhao et al., 2020b; Liu et al., 2020; Mizumoto and Chowell, 2020). The estimated R0 was 3.49 (95%CI: 3.42−3.58) by using exponential growth method based on the confirmed and suspected cases of COVID-19 in Hubei province (Wang et al., 2020). Taken together, these cases indicated that public transport and passenger terminal stations were likely to become vectors of the virus during the pandemic of COVID-19, resulting in the occurrence of clustered infection or a "super-spreading" event.

In the early stage of the pandemic in China, it was the Spring Festival holiday which was the most important holiday for Chinese people. The annual number of passengers during the Spring Festival is nearly 3 billion, and this is the period with the largest population movement in China every year. People return from their work places to their hometowns, visit relatives and friends, and purchase new year products. Public transport facilities are now increasing in popularity and is gradually being used as the principal method for trip. Human infection risks could be extremely high when considering the exposure time, transmission routes and structural characteristics during travel or work, resulting in the rapid spread of infections. A series of measures have been taken to curb the viral spread in public transport and passenger terminals, such as ventilation and sanitation of public transport vehicles and passenger terminals, regular disinfection, wearing of masks, hand hygiene, and maintenance of social distance. These measures have effectively curbed the cluster transmission of SARS-CoV-2 caused by public transport facilities.

The prevention and control during travel in public transportation will be utmost important when all countries in the world recover the economy and society. The aim of this study is to introduce experience of the prevention and control measures for public transportation in China to promote the global response to COVID-19.

2. Characteristics and transmission routes of the SARS-CoV-2

Coronaviruses are single-stranded, positive-sense RNA viruses with a genome of approximately 2.7-3.2 kb. SARS-CoV-2 is a betacoronavirus, and it has only about 70% homology with the SARS genome (National Health Commission of the People's Republic of China., 2020a; Gralinski and Menachery, 2020).

Droplets and close contact are the main routes of transmission. An aerosol transmission is plausible when exposure to high concentrations of aerosols for a long time in a relatively closed settings (National Health Commission of the People's Republic of China., 2020). Studies have shown that SARS-CoV-2 can survive for up to 3 h in aerosols, 4 h on the copper surface, 24 h on the cardboard surface, and up to 2-3 days on plastic or stainless steel surfaces under laboratory conditions with a relative humidity of 40%-65% and temperature of 21-23°C (Van Doremalen et al., 2020). Respiratory infections can spread via inhalation of droplets during talking, coughing, and sneezing, in addition to aerosol-generating procedures (AGPs) in clinics (Xie et al., 2009; Zhu et al., 2006). When a large amount of aerosols is generated, they remain suspended in air for a long time and spread over a long distance with air circulation (Kwon et al., 2012; Gralton et al., 2011; Chen et al., 2009; Yang et al., 2007). The risk of contamination and spread of the disease is greatly minimized when a social distance of 1−2 m is maintained (Gameiro Da, 2020).

The sources of COVID-19 are from both symptomatic and asymptomatic patients (National Health Commission of the People's Republic of China., 2020). A German person was infected by an asymptomatic person in the prodrome period of COVID-19 (Rothe et al., 2020). More attention should thus be paid to the fact that a substantial proportion of COVID-19 cases are asymptomatic. Asymptomatic patients may also have high viral loads, which are similar to those in symptomatic patients (Zou et al., 2020). A recent study in Ningbo showed that the infection rate of close contacts with asymptomatic patients was 4.11% within the followed-up of 2,147 close contacts (Chen et al., 2020). Another study in Wuhan found that at least 59% of infected cases were unascertained, potentially including asymptomatic and mildly symptomatic cases (Wang et al., 2020). The existence of asymptomatic infections makes it difficult to control the spread of COVID-19 since the virus can spread before symptoms appear. An increasing number of reports indicated that SARS-CoV-2 might be transmitted from people who are infected but still asymptomatic (Bai et al., 2020). It was suggested that viral testing should include those who had traveled to outbreak areas or were in close contact with confirmed cases (Lipsitch et al., 2020). Hence, it is now evident that everyone is susceptible, and the incubation period is 2-14 days (Li et al., 2020; Guan et al., 2020; Backer et al., 2020).

3. Precautionary and control strategies

SARS-CoV-2 is highly infectious and pathogenic, especially in the special environment of public transportation. Therfore, to prevent or control the disease spreading, many effective countermeasures need to be adopted, such as management measures, disinfections, environmental hygiene, personal protection and health promotion.

3.1. Institutional requirements

During the COVID-19 pandemic, it is important to establish effective coordination mechanisms and training measures, which can enable the prevention and control strategies to be implemented rapidly and effectively. In addition, disinfections, personal protection, environmental hygiene, and emergency measures are also necessary.

3.1.1. Formulatingguidelines and strengthening cooperation

Specific prevention and control guidelines should be developed in accordance with the environment, building layout, and transport and path characteristics of the public transport and passenger terminals. These measures, including personnel management, training and inspection, material support, health monitoring, and personal protection, should be formulated for different means of transport and passenger terminals. Multiple agencies should work together and design emergency work plans in advance. The management should be performed to ensure smooth cooperation.

3.1.2. Training and health education

Staff training, work supervision, and work inspection should be strengthened to improve risk and prevention awareness during the pandemic. Training should be conducted on prevention and control measures of COVID-19 at passenger terminals and on vehicles by using the video training courseware. The training could improve the ability of front-line staffs to prevent and control pandemics and to respond the emergency. Billboards, electronic screens, and electronic banners should be used to popularize the knowledge on infection prevention and control for staffs and passengers. Playing videos and distributing brochures on health protection knowledge can consolidate public awareness of protection.

3.1.3. Reserving materials and implementing safeguards

Adequate supplies of disinfectants, masks, and other disinfection and protection materials should be reserved to protect against pandemic. Front-line workers should have supplies such as gloves, masks, disinfectants, and temperature monitoring equipment. Hand-washing facilities should be equipped with hand sanitizers (or soaps) in public restrooms. If possible, alcohol-based hand sanitizer can be placed. Passenger terminals and public transport vehicles should be maintained properly to ensure adequate transport capacity. Transport vehicles should be kept in good condition to ensure transport safety.

3.1.4. Strengthening personnel management

Transportation departments should conduct comprehensive analysis and scientific judgment on the demand for transportation based on the pandemic situation. Passenger flow should be controlled according to the monitoring and forecasting transportation data. To avoid crowding, the number of passengers in passenger waiting areas should be controlled or reduced. The transport capacity must follow a unified plan to optimize operating arrangements. The management of ticket sales should be improved.

In order to minimize the probability of virus transmission through respiratory droplets and contact, passengers should keep the distance as far as possible from the others during ticketing, waiting, check-in, and so forth (Ministry of Transport of the People's Republic of China, 2020). Passengers need to register their personal information. Staffs of transportation departments need to strictly implement temperature detection for passengers. Individuals whose temperature exceeds 37.3 °C must visit the doctor immediately. Public transport workers, especially front-line workers, should perform daily health monitoring to ensure good health during work hours.

3.1.5. Strengthening ventilation and environmental cleaning and disinfection

In China, public transportation includes airplanes, high-speed rail, subways, buses, taxis, ships, etc. During this pandemic, we strengthened the ventilation, environmental cleaning and disinfection of airports, railway stations, passenger stations, buses, and other passenger stations and vehicles.

a. Enhance ventilation

A Japanese study using droplet infection model shows that ventilation can effectively reduce the concentration of suspended matters in confined spaces (Ifeng.com, 2020). Therefore, ventilation can be used to reduce the risk of close-range droplet transmission. Natural or mechanical ventilation can be adopted to clean air in different places and vehicles. The ventilation power of air conditioning and air charge rate should be increased, and air conditioning filters should be cleaned or replaced regularly in the relatively confined environment of airplanes, high-speed railways, and subways. If possible, windows should be opened to increase the air exchange when at low speeds or during the stops for short-distance passenger cars, buses, and other public transport vehicles.

b. Clean the environment

Passenger terminals and public transport vehicles should be kept clean and tidy. Wet cleaning is preferred to avoid re-suspension of dust. Garbage classification management should be strengthened and trashes should be collected and removed in time. Temporary storage areas and public restrooms should be kept clean.

c. Strengthen preventive disinfection

Passenger terminals, waiting rooms and public restrooms should be cleaned and disinfected daily. After each transport, the inner surface of public transport needs to be cleaned and disinfected. The inner surface can be disinfected by spraying or wiping with 250–500 mg/L of chlorine-containing disinfectant or wiping with an effective disinfecting wipe (General Office of the State Council's Joint Prevention and Control Mechanism, 2020). The frequency of cleaning and disinfecting surfaces with high frequency of contact should be increased. Seat covers and other textiles should be kept clean, washed and disinfected regularly. If there is vomit, it should be completely covered with disinfectant or dry disinfection towel and removed once finishing disinfection. The surface should then be subjected to conventional treatment.

3.1.6. Emergency

If an emergency happens at a passenger terminal or in a public transport vehicle, timely measures should be taken in accordance with the emergency response plan to avoid or reduce the adverse effects on companions. Emergency zones should be set up in passenger terminals and public transport vehicles. Three rows of seats in the rear of planes, trains, and buses can be used as emergency areas. The length of three rows should be at least 1 m, which is a safe distance to reduce the risk of infection. Passengers with fever, cough, or other symptoms should be immediately transferred to the emergency area for temporary isolation and then comply with the emergency response plan and local regulations. Passengers should be sent to the designated medical institution by a special car immediately. Other passengers and staffs should perform the personal protection. Terminal disinfection should be carried out for the potentially contaminated environment and subject surfaces by professionals.

3.2. Personal protection

Formulation of personal protection guidelines, including staff and passenger protection in public facilities, should be based on transmission routes of SARS-CoV-2 and standards of disinfection. Since the transmission of SARS-CoV-2 happens mainly through respiratory droplets and close contact, three major strategies of personal protection are wearing masks (Leung et al., 2020), performing hand hygiene, and keeping a safe social distance (over 1 m) when traveling on public transport vehicles. Hands should be washed with running water or rubbed with hand sanitizer. At least a 1-m social distance should be kept. The application method of disinfectant is based on the current Chinese disinfection standards.

3.2.1. Staffs

To minimize the risk at passenger terminals and public transport vehicles, staffs must ensure that they are in good health during work hours. Masks and work clothes should be worn when

working, and gloves can be worn if possible. Disposable gloves are not reusable. Reusable gloves need to be cleaned daily and disinfected regularly. Work clothes, gloves, and other fabric personal belongings should be disinfected by boiling them for 30 mins or soaking them in a chemical disinfectant (such as 500 mg/L chlorine-based disinfectant for 30 mins) (General Office of the State Council's Joint Prevention and Control Mechanism, 2020). Hand hygiene should be strengthened during work hours. Workers responsible for environmental cleaning and disinfection activities should also adopt personal protection against chemical disinfectants, such as wearing rubber gloves.

3.2.2. Passengers

To ensure safety and reduce the risk of infection, passengers must ensure that they are in good health when traveling. They should carry masks and other personal protective equipment. The hand sanitizer should be kept handy if possible. Masks should be worn throughout the journey in crowded places such as passenger terminals and public transport vehicles. The masks can be removed shortly during the security check and then worn immediately after the completion of facial recognition. Everyone should pass through the security check as soon as possible. Passengers should avoid touching door handles, elevator buttons, and other public facilities directly. Once touching, they should wash their hands or rub their hands with hand sanitizer in time. Attention should be paid to personal hygiene, and the mouth, eyes, or nose should not be touched with hands. Proper cough etiquette should be practiced and exercised. Stairs or escalators should be used, and a distance of more than 1 m from others should be maintained. Confrontation with others should be avoided. When using an elevator, a safe distance should be maintained from the others to avoid many people in the same elevator.

3.3. Knowledge promotion

Public transport—related prevention and control guidelines should be accessible through mainstream science media, short videos, WeChat, official accounts, new media, and webcasts, which increases national awareness toward COVID-19 and improves the ability of national public transport to prevent and control the disease. The knowledge on infection prevention and control during travel should be circulated in the form of videos and brochures on passenger terminals and vehicles to promote civilized behavior and safe travel, and to enhance the power of the society to response to infectious diseases.

4. Perspectives

Since March of 2020, China has gradually recovered society, and people have returned to work from their hometowns. The population movement across the country has increased dramatically. However, to date, there are no any cluster transmissions of COVID-19 caused by public transport facilities in China. Therefore, the effectiveness of these measures has been proved effectively (Chu et al., 2020), and we have no doubt that these measures could assist the efforts from preventing COVID-19 to spread.

The prevention and control of the disease during public transportation is particularly important when all countries in the world resume production. Health protection during public transportation requires the cooperation of various departments, organizations, and personnel. Under the supervision of transportation departments, the coordinated functioning of different departments, agencies, and personnel is of great significance to the prevention and control of this pandemic. With the deepening of the research on the virulence and transmission of SARS-CoV-2, the prevention and control measures for public transport vehicles and passenger terminals have become more scientific and targeted. Prevention and control measures should be adjusted according to the pandemic situation.

Author contributions

JS and XS had the idea for and designed the study. JS and HD contributed equally to this work. JS, HD, BZ and JW drafted the paper, and all authors critically revised the manuscript and gave final approval for the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to any part of the work are appropriately investigated and resolved.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envpol.2020.115291.

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